15B.6 MJO-LIKE COHERENT STRUCTURES IN IDEALIZED AQUAPLANET SIMULATIONS

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The Madden-Julian Oscillation (MJO, Madden and Julian 1994 and references therein) is the most spectacular example of tropical climate variability on intraseasonal time scales. MJO is a large-scale perturbation (zonal wavenumber 1-2) of surface pressure, cloudiness, precipitation, and winds discovered by Madden and Julian in the early seventies. MJO affects convection and surface winds only over the warm waters of the Indian Ocean and the tropical western Pacific, whereas the upper-

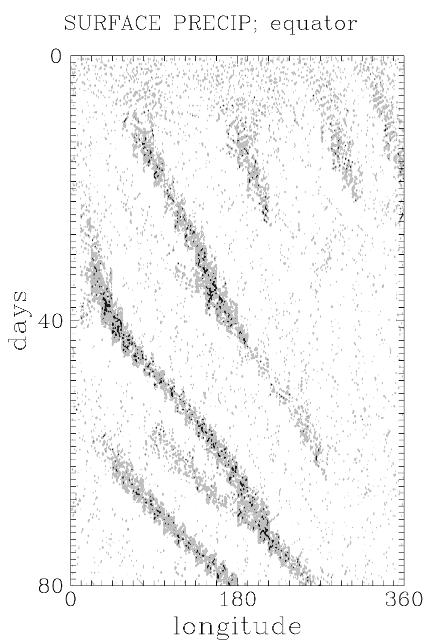

Figure 1: Hovmöller diagram of the surface precipitation rate at the equator for the CRCP global simulation. Precipitation intensities larger than 0.2 and 5 mm hr^{-1} are shown using light and dark shading, respectively.

tropospheric winds show a global impact. MJO propagates west-to-east with typical speeds between 5 and 10 m s^{-1}, i.e., it circumnavigates the Earth in several tens of days.

Previous studies have suggested a wide range of physical processes, such as coupling between moist convection and the large-scale dynamics (e.g., CISK-related ideas), radiative transfer, equatorial waveguide dynamics, and atmosphere-ocean interactions, to explain the fundamental mechanism behind the MJO. However, despite vigorous research in the past two decades, MJO remains an enigmatic feature of the large-scale dynamics in the tropics. This is mostly because MJO involves a vast range of spatial and temporal scales, from convective to global. Traditional approaches, which involve convective parameterizations in one way or another, show a frustrating sensitivity of MJO simulations to not only the convective scheme selected, but often to the scheme parameters. As a result, global models, even in idealized setups (e.g., aquaplanets) require considerable effort to produce a robust MJO simulation.

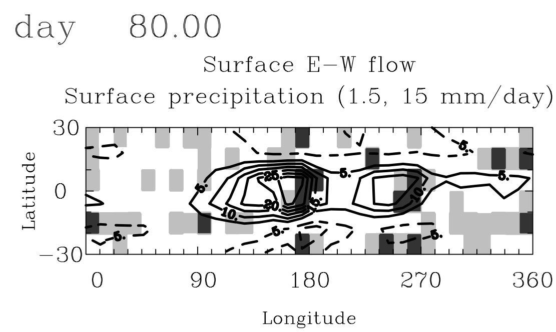

Figure 2: Spatial distribution of the surface zonal velocity (solid and dashed contours for positive and negative values, respectively; contour interval of 5 m s^{-1}) and the surface precipitation (averaged from CRCP model domains) using a gray scale (precipitation intensity larger than 1.5 and 15 mm day^{-1} shown using light and dark shading, respectively). Data for the simulation shown in Fig. 1 at day 80.00.

This paper presents results from idealized simulations using a nonhydrostatic general circulation model with Cloud-Resolving Convection Parameterization (CRCP, the "super parameterization"; Grabowski 2001, hereafter G01) pertinent to the large-scale organization of tropical convection. The cornerstone of CRCP is to use a 2D cloud-resolving model to represent the impact of cloud-scale pro-

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cesses — such as convective motions, precipitation formation and fallout, interaction of clouds with radiative and surface processes — in every column of a large-scale or global model. We consider an idealized problem of convective-radiative equilibrium on a rotating constant-SST aquaplanet with the size and rate of rotation of the Earth (see section 4 of G01). The important extension of the simulations reported previously (G01; Grabowski 2002, hereafter G02) is that an interactive radiation transfer model (Kiehl et al. 1994) is applied inside CRCP domains. This replaces prescribed radiative cooling applied in G01 and G02. We stress that the radiative transfer applies cloud-scale fields supplied by CRCP and it does not involve any subgridscale representation of cloud structure and overlap.

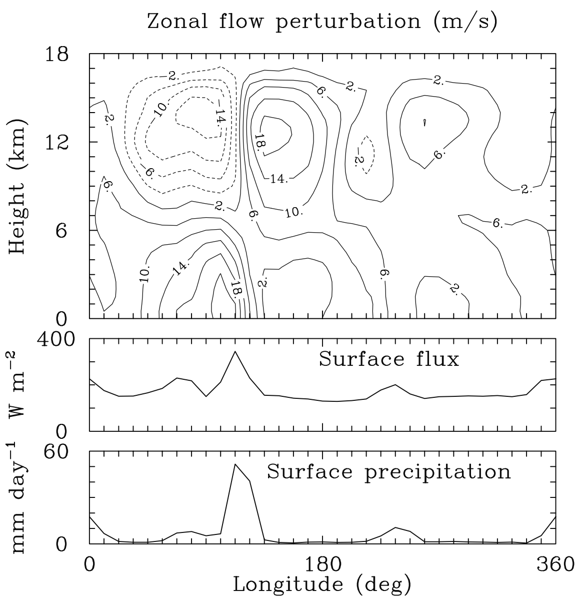

Figure 3: Zonal flow (plotted as a perturbation from the mean at each height) in the vertical plane at the equator (upper panel), and spatial distributions along the equator of the surface heat flux (sensible plus latent, middle panel) and surface precipitation (lower panel). The data for days 41-70 of the simulation shown in Fig. 1 averaged in the reference frame moving to the east with the speed of 7.5 ms^{-1}.

Convection outside the equatorial waveguide lacks large-scale organization throughout the entire simulation. Inside the waveguide, on the other hand, large-scale organization spontaneously develops as illustrated in Figure 1. The large-scale pattern, similar to that in prescribed-radiation simulations, propagates toward the east with a speed of around 8 m s^{-1}. The MJO-like coherent structures are illustrated in Fig. 2. The MJO wavenumber 2 pattern features leading-edge convection and strong surface westerly winds behind. The strong westerly surface winds to the west of deep convection are traditionally referred to as westerly wind bursts and are well known to follow strong convective periods associated with the passage of the MJO (cf. Fig. 16 in Lin and Johnson 1996). The vertical structure of the large-scale flow within the equatorial waveguide is shown in Fig. 3. The figure shows that strong surface winds behind the leading edge convection are accompanied by strong easterly flow aloft. This also agrees with Lin and Johnson's (1996) analysis. The large-scale pattern has a significant westward tilt.

The pattern shown in Figs. 1 to 3 is very robust. It develops in several variants of the simulation shown herein (e.g., using different surface flux algorithms, microphysical parameterizations, etc). This is in stark contrast to simulations which apply traditional convective parameterizations, which typically show a strong sensitivity to the specific convective scheme and/or scheme parameters that are employed.

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